Great Basin Naturalist 54(3), © 1994, pp. 272–286

OBSERVATIONS ON DOUBLE-CRESTED CORMORANTS (*PHALACROCORAX AURITUS*) AT SPORTFISHING WATERS IN SOUTHWESTERN UTAH

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ABSTRACT.—Counts of Double-crested Cormorants (*Phalacrocorax auritus*) were made at 13 reservoirs and lakes in southwestern Utah during 1989–91 to determine current abundance of that species. Food habits of cormorants were studied at three of the reservoirs in 1989. Data were also collected on trout abundance during standardized gill-netting to make comparisons between cormorant numbers and trout abundance. Cormorants were observed at all waters studied except one and were generally most numerous during the spring as they migrated through the area. Estimated cormorant abundance ranged from 0 to 34 bird-days per ha and was highest at the larger, lower-elevation reservoirs. Cormorants were summer residents at several of the larger reservoirs and nested successfully at Piute Reservoir. Trout accounted for 24–81% of the diet of cormorants, with Utah chubs constituting most of the remainder of the diet. Estimates of the annual consumption of fish by cormorants ranged from 0 to 15.8 kg per ha. The index of trout abundance was inversely related to cormorant abundance ($P < .01$) at the waters studied. Cormorants apparently have increased in numbers and extended their range in southwestern Utah during the past decade. This change may be the result of factors that have led to similar changes throughout North America as well as some factors unique to Utah. Methods to mitigate the impact of predation by piscivorous birds on sportfisheries are discussed. The Utah Division of Wildlife Resources has initiated a new management plan at Minersville Reservoir that incorporates piscivorous birds into sportfish management at that reservoir.

Key words: cormorants, Phalacrocorax auritus, *trout, abundance, food habits, predation, management, sport fishing, reservoirs, Utah.*

Various factors influencing survival of stocked trout were examined at Minersville Reservoir, Utah, in 1985–88 (Hepworth and Duffield 1991, Wasowicz 1991). During that study we observed an increase in the number of Double-crested Cormorants (*Phalacrocorax auritus,* hereafter referred to as cormorants) at Minersville Reservoir compared with previous years. An apparent increase in the abundance of cormorants at several other reservoirs was also noted, and we received reports of cormorants at some waters where they previously had not been reported (Walters and Sorenson 1983). Apparent changes in abundance and distribution of this species in Utah coincided with reported increases in the number of cormorants in many parts of North America (Price and Weseloh 1986, Christie et al. 1987, Campo et al. 1988, Findholt 1988). As the relative abundance of cormorants has increased, there have been conflicting reports concerning their impact on recreational fisheries. A number of authors have concluded that cormorants take considerable numbers of game fish and potentially impact important fisheries (Ayles et al. 1976, Myers and Peterka 1976, Christie et al. 1987, Campo et al. 1988). Others have felt that cormorants have had little impact on economically valuable species of fish (Baillie 1947, Carroll 1988, Findholt 1988). To evaluate the potential impact of cormorants on fisheries in southwestern Utah, we continued to document the number of cormorants at Minersville Reservoir and 12 additional waters. We also collected data on trout abundance at these waters during standardized annual gill-netting and initiated a study of the food habits of cormorants at three of the larger reservoirs. Based on these observations, we determined current abundance of cormorants at local waters, compared estimates of cormorant abundance to indices of trout abundance, and estimated annual consumption of fish by cormorants.

STUDY AREA

Data on distribution, relative abundance, and seasonal occurrence of cormorants were

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collected at 13 reservoirs in southwestern Utah (Table 1). Reservoirs ranged in size from 36 to 1020 ha, and elevations from 910 to 2695 m above MSL. Most reservoirs were originally constructed for irrigation storage and have water levels that fluctuate substantially on an annual basis. Highest water levels occurred in late winter and spring, with minimum levels in the fall following the irrigation season. Fish Lake and Panguitch Lake are natural lakes where storage has been increased by the addition of small dams. All the reservoirs except Quail Creek and Gunlock had ice cover for a period of 2–5 months during winter and spring.

Sportfishing is a major activity at all of the waters since they are open year-round to angling by the general public with various restrictions (State of Utah 1992). Sportfisheries at all reservoirs except Gunlock are managed, at least in part, as put-grow-and-take trout fisheries. Various sizes and numbers of rainbow trout (*Oncorhynchus mykiss*) were stocked annually at the different reservoirs. Fingerling rainbow (76 mm total length [TL]) were stocked at waters where numbers of competing species were low and predation was not a concern. Larger rainbow (127–178 mm TL) were stocked at reservoirs where survival of small trout was poor because of competition with nongame species and/or predation. Limited numbers of other species of trout were stocked at some waters to provide variety in fishing opportunity. Recruitment from spawning in tributaries associated with reservoirs also provided a small number of trout in addition to those stocked at some of the study waters. Stocked trout were harvested by anglers after they reached a catchable size (>230 mm TL), generally after they had been in the reservoirs for 7–11 months. Few rainbow trout survive longer than 2 years following stocking (Stuber et al. 1985, Hume and Tsumura 1992). Most reservoirs contained few fish species other than trout, and five contained primarily stocked trout (Enterprise, Kolob, Koosharem, Lower Bowns, and Newcastle). Three of the reservoirs contained only stocked trout and Utah chubs (*Gila atraria*; Minersville, Otter Creek, and Panguitch). Two were primarily warm-water fisheries where trout abundance was not evaluated (Gunlock and Quail Creek). The remaining three waters (Fish Lake, Johnson and Piute reservoirs) contained more than two other fish species besides trout. Only two or three of these other species were abundant, while the rest were of minor occurrence.

A number of the waters in which Utah chubs and Utah suckers (*Catastomus ardens*) occurred were periodically treated with rotenone to remove all fish when those nongame species became abundant. When reclamation projects were conducted, chubs and suckers often outnumbered trout by hundreds to one. Following treatments, trout were the

TABLE 1. Description of waters in southwestern Utah where scheduled counts of Double-crested Cormorants were conducted, 1989-91.

Water	Location	Elevation (m)	Maximum surface area (ha)	Fish species present[a]	
				Common	Uncommon
Enterprise Reservoir	T38S R18W, Washington Co.	1755	200	RT	
Fish Lake	T26S R2E, Sevier Co.	2695	1012	RT, LT, SP, US, UC, YP	RS, MS
Gunlock Reservoir	T40S R17W, Washington Co.	1092	108	CC, LB, GS	BC, BG
Johnson Reservoir	T25S R2E, Sevier Co.	2688	285	RT, CT, UC, US	YP, RS
Kolob Reservoir	T38S R11W, Washington Co.	2474	136	RT, CT, BK	
Koosharem Reservoir	T25S R1E, Sevier Co.	2132	125	RT, CT, BK	
Lower Bowns Reservoir	T31S R6E, Garfield Co.	2271	36	RT, CT, BK	
Minersville Reservoir	T29S R8W, Beaver Co.	1677	401	RT, CT, UC	BN
Newcastle Reservoir	T36S R15W, Iron Co.	1659	66	RT	SB
Otter Creek Reservoir	T29S R2W, Piute Co.	1942	1020	RT, UC	CT, BN
Panguitch Lake	T35S, R7W, Garfield Co.	2502	505	RT, BK, BN, CT, UC	
Piute Reservoir	T28S, R2W, Piute Co.	1828	1015	RT, UC, US	BN, CT, RS, SB
Quail Creek Reservoir	T42S, R14W, Washington Co.	910	239	RT, LB, BC, BG	BB

[a]Fish species: RT = rainbow trout, GS = green sunfish, LT = lake trout, SP = splake trout, US = Utah sucker, UC = Utah chub, YP = yellow perch, MS = mottled sculpin, CC = channel catfish, LB = largemouth bass, BC = black crappie, BG = bluegill, CT = cutthroat trout, BK = brook trout, RS = redside shiner, BN = brown trout, SB = smallmouth bass, BB = black bullhead.

predominant species for at least a year or two. In situations where undesirable nongame species of fish could not be completely removed from a drainage, Utah chubs and Utah suckers would gradually increase and eventually return to pre-reclamation densities.

In addition to cormorants, other piscivorous birds observed at the study waters included Common Loons (*Gavia immer*), Western Grebes (*Aechmophorous occidentalis*), American White Pelicans (*Pelecanus erthrorychos*), Mergansers (*Mergus merganser* and *M. serrator*), and Great Blue Herons (*Ardea herodias treganzai*).

METHODS

Counts of cormorants were made at 1- to 3-week intervals at 11 reservoirs during 1989. In 1990 we made biweekly counts at four of the larger reservoirs. Counts were made again in 1991 at the four reservoirs surveyed in 1990, as well as three additional ones. Counts generally began following ice-out at each reservoir and continued through November at most waters. We discontinued counts early at several reservoirs that were drained during the summer or chemically treated to remove nongame fish. At most locations counts were made from shore using binoculars or a spotting scope. At larger reservoirs we often used a boat to facilitate counting. Technicians making counts were instructed using a standard training program by the authors. The same one or two technicians counted birds at all waters during any one year of the study. Cormorants were easily identified. Knowledge of the birds' feeding and resting patterns, as well as other behaviors, also aided in making accurate counts.

An annual estimate of cormorant abundance (bird-days per ha per year) was made for each reservoir studied. The estimate of abundance was calculated using methods commonly employed to estimate sportfishing pressure in creel surveys of anglers (Robson 1960, Lambou 1961). A bird-day was defined as one day spent by one cormorant at a given water. The sampling period was stratified by 3-month intervals, March–May, June–August, and September–November. The number of days within a stratum varied among waters, depending on the time of ice-out and whether a given reservoir was drained or treated in the fall. The number of bird-days for a stratum at a given water was estimated using the following formula:

$$D = K\left(\frac{\sum x_i}{n}\right)$$

$$Var\,(D) = \frac{K^2\left(\sum x_i^2 - \frac{N^2}{n}\right)}{(n-1)\,n}$$

where:

D = estimated total bird-days;
K = number of days within a sampling stratum;
x_i = number of cormorants counted on the i^{th} day;
n = number of days sampled within a stratum;
Var = estimated variance;
N = total cormorants counted per stratum.

$$95\%\ \text{confidence interval} = \pm\, 2\sqrt{Var\,(D)}.$$

The estimate of annual cormorant abundance was the sum of estimated bird-days for strata within a sampling year divided by the mean surface area of the reservoir.

Gill-nets were used to estimate trout abundance at each reservoir (Bennett 1962, Hubert 1983) during early spring, 2–4 weeks after winter ice cover was completely gone. Net numbers, styles, and locations were based on long sampling histories at each water. Gill-net data have been collected on most of the study waters for 10 years or more. We followed standardized netting practices used by the Utah Division of Wildlife Resources (UDWR). Two to six nets, depending on lake or reservoir size, were set at each water in areas less than 30 ft deep. Nets were set during the afternoon and retrieved the following morning. Each net was 1.8 m deep by 38.1 m long and consisted of five monofilament nylon panels with bar mesh sizes of 19.1, 24.4, 31.8, 38.1, and 50.8 mm.

Data recorded for fish gill-netted at each water included numbers, species, and individual lengths. Gill-net samples generally consisted of trout stocked the previous year and a few from stocking 2 years earlier. The trout abundance index used for each reservoir in the study was the mean number of trout collected per net, set overnight (trout per net-night). When comparing trout abundance and estimates of cormorant abundance, we paired the trout abundance index for a given water with the estimate of cormorant abundance for the previous year. Because spring gill-net catches consisted primarily of trout stocked the previous year, the relationship between the cormorant abundance estimate and trout abundance index reflected impacts of predation on one cohort of stocked trout over one year. Large trout were excluded from the data at two waters when calculating the trout abundance index. These larger fish represented older cohorts that were not vulnerable to cormorant predation during the study period. Large trout occurred at Minersville Reservoir and Fish Lake as the result of unusual circumstances or the presence of unique trout populations. At Fish Lake a few large lake trout (*Salvelinus namayacush*) were not used in the index. One cohort of cutthroat trout (*Oncorhynchus clarki*) at Minersville Reservoir was not used in the trout abundance index for that reservoir. This 1986 cohort grew rapidly to a large size following a chemical renovation in 1985 and comprised a substantial portion of the annual spring gill-net catches through 1991. A simple linear regression was used to compare estimates of cormorant abundance (bird-days) and the trout abundance index (trout per net-night) using both untransformed data and log-transformed data.

Data on cormorant diet were collected at three large, lower-elevation reservoirs where birds were relatively abundant. At Minersville and Otter Creek reservoirs, primary potential fish prey species were stocked rainbow trout and Utah chubs, with lesser numbers of cutthroat trout and brown trout (*Salmo trutta*). At Piute Reservoir primary prey species included rainbow trout, Utah chubs, and Utah suckers. Piute Reservoir also contained limited numbers of redside shiners (*Richardsonius balteatus*), smallmouth bass (*Micropterus dolomieui*), cutthroat trout, and brown trout. We collected 10 cormorants each at Minersville, Otter Creek, and Piute reservoirs (30 birds total). Birds were collected using shotguns during July and August at 1000–1100 h following morning feeding periods. We also used food-habit data collected by Wasowicz (1991) at Minersville Reservoir in April 1988, which included cormorants collected during afternoon hours. Additional food-habit information was obtained from six fledgling cormorants at Piute Reservoir in 1989 by approaching active nests and collecting regurgitated stomach contents. In total, diet data were obtained from 52 cormorants, with samples taken in mid-April, late April, late June, late July, early August, and late August.

Stomach contents were identified to fish species using flesh color, peritoneum color, fin rays, and pharyngeal teeth as key characteristics. We made TL measurements of ingested fish when possible. TL estimates were also based on a measurement from the front of the dorsal fin to the front of the anal fin. Estimates of biomass of ingested fish were made using length-weight relationships for each species (Carlander 1969, Varley and Livesay 1976).

Annual trout consumption by cormorants was estimated by multiplying values for bird abundance (bird-days) by a daily biomass consumption rate of 465 g per day (after Wasowicz 1991), and by the percentage of trout in the diet (this study, Wasowicz 1991). The daily biomass consumption rate used by Wasowicz (1991) and this study was based on an average adult body weight for cormorants of 1860 g (Ross 1977) and a daily biomass consumption rate of 25% of body weight. Dunn (1975) reported that daily consumption rates for free-living adults and juveniles of several species of cormorants averaged approximately 20–30% of body weight. When information on diet composition of cormorants was not available for a particular water, we made a conservative estimate of the percentage of trout in the diet by determining relative abundance of trout and other forage species in that water.

Season-long creel surveys of sport fishermen and chemical treatment projects to remove undesirable nongame fish were conducted at a number of study waters. Although not directly related to this study, data collected during these activities provided a means to validate trout abundance indices and verify relative abundance of different fish species. We estimated total annual trout harvest by anglers and the percent return to the creel of the total numbers of fish stocked (Robson 1960, Lambou 1961) during creel surveys. High and low harvest estimates corresponded with high and low trout abundance as measured by standardized gill-netting. Visual inspections following chemical treatments provided another way of verifying relative fish abundance and species composition. Following a chemical treatment, we could be certain that stocked trout dominated a fishery for a year or two. Creel surveys were conducted at Fish Lake in 1989, Johnson Reservoir in 1984 and 1989, Kolob Reservoir in 1991, Lower Bowns Reservoir in 1991, Minersville Reservoir in 1986 and 1988, Newcastle Reservoir in 1991, and Otter Creek Reservoir in 1985. Chemical treatments were conducted at Johnson Reservoir in 1986, Kolob Reservoir in 1985, Koosharem Reservoir in 1985, Minersville Reservoir in 1984 and 1991, Otter Creek Reservoir in 1989, Panguitch Lake in 1991, and Piute Reservoir in 1985 and 1990.

RESULTS

Cormorant Distribution and Abundance

Eight to 35 counts were made at each of the 13 reservoirs (Table 2). Individual counts of cormorants ranged from 0 to 264 birds. Cormorants were observed early in the year (2 February 1989) at Quail Creek Reservoir, which was the lowest in elevation and most southern reservoir studied. At most other waters, cormorants were first observed soon after ice-out, usually in March. Numbers of cormorants were generally highest in spring or early summer. At lower-elevation waters, cormorants were often absent during midsummer but were observed again in late summer or fall. At some higher-elevation waters, highest counts occurred in midsummer. They were present throughout the summer at several of the larger reservoirs. Cormorants were observed at all waters surveyed except one, Lower Bowns Reservoir, the smallest and most easterly located.

Cormorants attempted to nest at 2 of the 13 locations studied. In 1988 and 1989 nesting was initiated at Minersville Reservoir. Cormorants constructed nests in a flooded grove of cottonwood trees in the shallow north end of the reservoir. The nests were abandoned, however, in late spring when the water level receded beyond the nesting trees. Water levels at Minersville Reservoir remained low during the spring of 1990 and 1991. The area in which nesting had been attempted the previous 2 years remained some distance above the shoreline, and cormorants made no further attempts to nest. Cormorants did nest successfully at Piute Reservoir in 1989 and 1990. On 26 June 1989, 45 fledgling cormorants were observed in nests in flooded cottonwood trees in the south end of that reservoir. In 1990, 55 pairs of nesting birds were observed in the same area on 11 April. Young cormorants were observed in 16 of the nests on 26 May 1990, in spite of rapidly dropping water levels that had left nesting trees well above the shoreline. Piute Reservoir was drained in the fall of 1990 causing water levels to remain low in 1991 and exposing the ground below trees used for nesting the previous 2 years. No nesting activity was observed at any of the locations studied in 1991.

Estimates of cormorant abundance at the 13 reservoirs ranged from 0 bird-days at Lower Bowns Reservoir in 1991 to 20,329 bird-days at Otter Creek Reservoir in 1989 (Tables 2 and 3). When we accounted for the size of various waters surveyed, cormorant abundance was highest at Minersville Reservoir where we estimated 34 bird-days per ha for 1989 (Table 4). Cormorant abundance was low at most of the higher-elevation waters, such as Kolob Reservoir, Johnson Reservoir, and Fish Lake.

Trout Abundance

Stocking rates ranged from 186 to 669 trout per ha per year at the waters studied, except at Gunlock Reservoir, which was managed only for warm-water species. In general, numbers and sizes of trout stocked at each reservoir or lake were considered sufficient to produce high numbers of catchable-size trout providing that survival was adequate. Trout abundance indices at the waters surveyed ranged from 1 to 91 trout per net-night (Table 4). Our past experience indicates that trout abundance indices of at least 25–30 fish per net-night yield a population of trout that will produce good fishing during the year. Rainbow trout accounted for the majority of the gill-net catch at most waters. The trout abundance index was inversely related to estimates of cormorant abundance ($P \leq .01$, Fig. 1). Although a log transformation of cormorant abundance data statistically improved the fit of the regression line, the negative relationship was also significant ($P < .05$) for the original, untransformed data. Trout abundance indices were low when bird abundance was greater than 15 cormorant-days per ha. Both high and low trout abundance indices occurred with low cormorant abundance; however, there

TABLE 2. Statistics from cormorant counts at 13 reservoirs in southwestern Utah, 1989–91.

Water/Year/Statistic	Time of year Mar–May	Jun–Aug	Sep–Nov	Total
Otter Creek Reservoir, 1989				
Total days in interval	78	92	52	222
Number of counts	12	7	5	24
Mean birds per count	65	135	56	92
Estimated bird-days	5044	12,394	2891	20,329
Standard error (bird-days)	883	715	947	1479
95% confidence interval	±1765	±1431	±1894	±2958
Otter Creek Reservoir, 1990				
Total days in interval	76	92	61	229
Number of counts	6	6	3	15
Mean birds per count	2	11	8	7
Estimated bird-days	139	1043	488	1670
Standard error (bird-days)	53	563	347	663
95% confidence interval	±107	±1126	±694	±1327
Otter Creek Reservoir, 1991				
Total days in interval	76	92	61	229
Number of counts	5	6	2	13
Mean birds per count	53	7	0	20
Estimated bird-days	4013	675	0	4688
Standard error (bird-days)	1204	357	0	1256
95% confidence interval	±2407	±714	±0	±2511
Newcastle Reservoir, 1989				
Total days in interval	92	92	91	275
Number of counts	9	6	7	22
Mean birds per count	6	0	1	2
Estimated bird-days	593	0	65	658
Standard error (bird-days)	114	0	52	125
95% confidence interval	±228	±0	±103	±250
Newcastle Reservoir, 1991				
Total days in interval	92	92	31	215
Number of counts	18	18	3	39
Mean birds per count	3	t[a]	1	1
Estimated bird-days	240	15	21	276
Standard error (bird-days)	103	8	21	105
95% confidence interval	±206	±17	±41	±210
Minersville Reservoir, 1989				
Total days in interval	92	92	56	240
Number of counts	14	12	7	33
Mean birds per count	78	33	11	45
Estimated bird-days	7209	3067	624	10,900
Standard error (bird-days)	1785	475	190	1856
95% confidence interval	±3569	±949	±379	±3712
Minersville Reservoir, 1990				
Total days in interval	92	92	61	245
Number of counts	12	11	2	25
Mean birds per count	64	14	3	30
Estimated bird-days	5850	1296	153	7299
Standard error (bird-days)	1265	317	153	1313
95% confidence interval	±2529	±634	±305	±2625
Minersville Reservoir, 1991				
Total days in interval	92	92	30	214
Number of counts	7	6	2	15
Mean birds per count	31	1	0	14
Estimated bird-days	2852	107	0	2959
Standard error (bird-days)	963	77	0	966
95% confidence interval	±1926	±153	±0	±1931

TABLE 2. Continued.

Water/Year/Statistic	Time of year: Mar–May	Jun–Aug	Sep–Nov	Total
Piute Reservoir, 1989				
Total days in interval	82	92	91	265
Number of counts	11	7	8	26
Mean birds per count	70	65	12	48
Estimated bird-days	5702	5967	1081	12,750
Standard error (bird-days)	690	1358	605	1639
95% confidence interval	±1380	±2715	±1209	±3277
Piute Reservoir, 1990				
Total days in interval	92	92	0	184
Number of counts	7	6	0	13
Mean birds per count	60	29	0	45
Estimated bird-days	5559	2683	0	8242
Standard error (bird-days)	1395	670	0	1548
95% confidence interval	±2790	±1341	±0	±3095
Piute Reservoir, 1991				
Total days in interval	82	92	—	174
Number of counts	5	6	—	11
Mean birds per count	2	5	—	4
Estimated bird-days	180	475	—	655
Standard error (bird-days)	160	196	—	253
95% confidence interval	±320	±392	—	±506
Fish Lake, 1989				
Total days in interval	82	92	74	248
Number of counts	4	6	5	15
Mean birds per count	0	t	0	t
Estimated bird-days	0	15	0	15
Standard error (bird-days)	0	15	0	15
95% confidence interval	±0	±31	±0	±31
Panguitch Reservoir, 1989				
Total days in interval	71	92	73	236
Number of counts	4	5	5	14
Mean birds per count	1	6	5	4
Estimated bird-days	71	570	365	1006
Standard error (bird-days)	71	128	247	287
95% confidence interval	±142	±256	±493	±573
Panguitch Reservoir, 1990				
Total days in interval	49	92	61	202
Number of counts	7	12	3	22
Mean birds per count	6	25	13	17
Estimated bird-days	301	2285	773	3359
Standard error (bird-days)	121	175	458	505
95% confidence interval	±242	±349	±917	±1010
Panguitch Reservoir, 1991				
Total days in interval	30	92	0	122
Number of counts	2	6	0	8
Mean birds per count	0	5	0	4
Estimated bird-days	0	429	0	429
Standard error (bird-days)	0	272	0	272
95% confidence interval	±0	±543	±0	±543

TABLE 2. Continued.

Water/Year/Statistic	Time of year: Mar–May	Jun–Aug	Sep–Nov	Total
Koosharem Reservoir, 1989				
Total days in interval	92	92	11	195
Number of counts	10	6	2	18
Mean birds per count	0	1	1	t
Estimated bird-days	0	46	6	52
Standard error (bird-days)	0	21	6	21
95% confidence interval	±0	±41	±11	±43
Johnson Reservoir, 1989				
Total days in interval	31	92	58	181
Number of counts	3	6	4	13
Mean birds per count	0	t	0	t
Estimated bird-days	0	31	0	31
Standard error (bird-days)	0	31	0	31
95% confidence interval	±0	±61	±0	±61
Enterprise Reservoir, 1989				
Total days in interval	71	92	88	251
Number of counts	9	6	6	21
Mean birds per count	4	1	t	1
Estimated bird-days	252	77	29	358
Standard error (bird-days)	147	50	29	158
95% confidence interval	±295	±100	±59	±317
Lower Bowns, 1991				
Total days in interval	31	92	61	184
Number of counts	6	17	12	35
Mean birds per count	0	0	0	0
Estimated bird-days	0	0	0	0
Standard error (bird-days)	0	0	0	0
95% confidence interval	±0	±0	±0	±0
Kolob Reservoir, 1991				
Total days in interval	31	92	61	184
Number of counts	3	18	14	35
Mean birds per count	t	t	t	t
Estimated bird-days	10	5	4	19
Standard error (bird-days)	10	5	4	12
95% confidence interval	±21	±10	±9	±25
Gunlock Reservoir, 1989				
Total days in interval	92	92	91	275
Number of counts	10	7	6	23
Mean birds per count	8	0	t	3
Estimated bird-days	727	0	15	742
Standard error (bird-days)	296	—	15	297
95% confidence interval	±592	±0	±30	±593
Quail Creek Reservoir, 1989				
Total days in interval	92	92	91	275
Number of counts	12	7	6	25
Mean birds per count	3	0	1	1
Estimated bird-days	284	0	91	375
Standard error (bird-days)	167	—	30	170
95% confidence interval	±334	—	±60	±339

[a]t = cormorants present but mean number of birds per count was less than 0.1.

TABLE 3. Estimated annual consumption of fish by cormorants at 13 reservoirs in southwestern Utah, 1989–91.

Water	Year	Survey period	Total bird-days (95% C.I.)	Estimated[a] annual fish consumption (kg)	Percent trout in diet	Annual trout consumption (kg)
Lower Bowns	91	1 May–31 Oct	0 (±0)	0	—	0
Enterprise	89	22 Mar–27 Nov	358 (±317)	166	100[c]	166
Fish Lake	89	10 Apr–13 Nov	15 (±31)	7	80[c]	6
Gunlock	89	1 Mar–30 Nov	742 (±593)	345	0	0
Johnson	89	1 May–28 Oct	31 (±61)	14	80[c]	12
Kolob	91	1 May–28 Oct	19 (±25)	9	100[c]	9
Koosharem	91	1 Mar–11 Sep	52 (±43)	24	80[c]	19
Minersville	89	1 Mar–26 Oct	10,900 (±3712)	5069	44[b]	2230
Minersville	90	1 Mar–31 Oct	7299 (±2625)	3394	44[b]	1493
Minersville	91	1 Mar–30 Oct	2959 (±1931)	1376	44[b]	605
Newcastle	89	1 Mar–30 Nov	658 (±250)	306	80[c]	245
Newcastle	91	1 Mar–10 Oct	276 (±210)	128	80[c]	103
Otter Creek	89	14 Mar–21 Oct	20,329 (±2958)	9453	80[b]	7562
Otter Creek	90	16 Mar–31 Oct	1670 (±1327)	777	90[c]	699
Otter Creek	91	16 Mar–31 Oct	4688 (±2511)	2180	90[c]	1962
Panguitch	89	21 Mar–12 Nov	1006 (±573)	468	80[c]	374
Panguitch	90	12 Apr–31 Oct	3359 (±1010)	1562	80[c]	1250
Panguitch	91	2 May–31 Aug	429 (±543)	199	80[c]	160
Piute	89	10 Mar–30 Nov	12,750 (±3277)	5929	55[b]	3261
Piute	90	1 Mar–31 Aug	8242 (±3095)	3833	55[b]	2108
Piute	91	10 Mar–31 Aug	655 (±506)	305	80[c]	244
Quail Creek	89	1 Mar–30 Nov	375 (±339)	174	44[c]	77

[a]Estimated annual consumption was calculated using a daily consumption rate of 465 g per bird per day and assuming only fish were eaten.
[b]Based on food habit data collected at given waters during this study (Table 5).
[c]Based on conservative estimates from relative abundance of forage species in gill-netting samples and history of the reservoir.

were no cases that had both a high trout abundance index and high bird abundance.

Cormorant Food Habits

Stomach contents from 30 adult and 6 nestling cormorants from three reservoirs were examined (Table 5). Stomachs from 7 (23%) of the 30 adults were empty. Food items identified were primarily trout and Utah chubs. One smallmouth bass and one crayfish were identified from collections taken at Piute Reservoir. Trout accounted for 24–81% (biomass) of the diet of cormorants at the three locations sampled. During similar sampling in April 1988, Wasowicz (1991) reported that trout comprised 97% of the diet of cormorants at Minersville Reservoir. Trout in the stomach samples from the three locations ranged in size from 100 to 396 mm TL, although most trout had been stocked about 10 months earlier and were typically greater than 230 mm TL. Utah chubs comprised 19–76% of the cormorant diet by weight. Utah chubs from stomach samples were 48–275 mm TL. Most cormorants contained only one species of prey. Only two of the birds examined contained both Utah chubs and trout.

Estimates of the annual total biomass of fish consumed by cormorants ranged from 0 kg at Lower Bowns Reservoir to 9453 kg at Otter Creek Reservoir (Table 3). Based on reservoir area, Minersville Reservoir had the highest estimated annual consumption of fish at 15.8 kg per ha. Estimates of annual trout biomass consumed by cormorants ranged from 0 to 7562 kg.

DISCUSSION

Distribution, relative abundance, and seasonal occurrence of cormorants in Utah has changed over the past decade. After a review of the available information and following visits to all recorded nesting sites in the state, Mitchell (1977) concluded that the population of cormorants in Utah had been steadily decreasing for the past 50 years. He reported that the total known cormorant population of Utah in 1973 consisted of only 386 cormorants nesting in five colonies, all associated with the Great Salt Lake or Utah Lake. More recently, Walters and Sorenson (1983) listed the cormorant only as a spring and/or fall migrant south of latitude 39°N in Utah. Hedges (1986)

TABLE 4. Estimates of cormorant abundance compared to trout abundance indices at southwestern Utah reservoirs, 1989–92.

Water	Sample Years: Cormorant abundance estimate	Sample Years: Trout density index	Letter identification	Estimated total bird-days (95% C.I.)	Mean reservoir surface area (ha)	Bird-days per ha (95% C.I.)	Number of gill-nets	Trout per net-night[a]
Lower Bowns	1991	1992	A	0 (±0)	27	0 (±0)	2	26
Enterprise	1989	1990	B	358 (±317)	150	2.4 (±2.1)	2	69
Fish Lake	1989	1990	C	15 (±31)	1000	t[c] (±0)	6	15[b]
Johnson	1989	1990	D	31 (±61)	214	0.1 (±0.3)	3	91
Minersville	1989	1990	E	10,900 (±3712)	321	34.0 (±11.5)	4	3[b]
Minersville	1990	1991	F	7299 (±2625)	301	24.2 (±8.7)	4	1[b]
Newcastle	1989	1990	G	658 (±250)	53	12.4 (±4.7)	3	6
Newcastle	1991	1992	H	276 (±210)	50	5.5 (±4.2)	4	27
Otter Creek	1990	1991	I	1670 (±1327)	765	2.2 (±1.7)	3	39
Otter Creek	1991	1992	J	4688 (±2511)	765	6.1 (±3.3)	4	13
Panguitch	1989	1990	K	1006 (±573)	450	2.2 (±1.2)	3	15
Panguitch	1990	1991	L	3359 (±1010)	400	8.4 (±2.5)	3	31
Piute	1989	1990	M	12,750 (±3277)	812	15.7 (±4.0)	4	18

[a]Trout abundance index was calculated as the mean number of trout collected per net-night during standardized spring gill-net sampling.
[b]Trout abundance indices did not include large trout collected at two reservoirs as explained in text.
[c]t = less than 0.1 bird-days per ha.

also reported that cormorants were only spring and fall migrants at Minersville Reservoir from 1983 through 1986. During our study cormorants were summer residents at Minersville Reservoir in 1989 and 1990. They were also present through the summer in 1989, 1990, and 1991 at Piute and Otter Creek reservoirs. At Panguitch Lake, cormorants were summer residents during 1989 and 1990. As noted above, cormorants nested successfully in at least one location in southwestern Utah in 1989 and 1990. The single highest count of cormorants at Minersville during 1988 (Wasowicz 1991) was nearly as high as the total Utah population of cormorants in 1973 (Mitchell 1977).

Changes in cormorant abundance and distribution observed in southwestern Utah coincide with reported increases of cormorants in other areas of Utah and in the rest of North America. New rookeries have been reported at Hyrum Reservoir, Cache County, Utah (T. Pettengill, UDWR, personal communication), and Mona Reservoir, Juab County, Utah (D. Shirley, UDWR, personal communication). Large increases in the number of cormorants in other regions of North America since the early 1900s have been well documented (Price and Weseloh 1986, Christie et al. 1987, Campo et al. 1988, Findholt 1988). Factors cited for the increases nationwide include protection of cormorants by federal and state statutes, prohibitions against the use of chlorinated hydrocarbons as pesticides, and the creation of new suitable habitats. Changes in cormorant distribution and abundance in Utah are a function of the same factors as well as others peculiar to the state. Increases reported at various locations in Utah occurred after a rise in the water level of the Great Salt Lake in the mid-1980s. There was considerable loss of habitat and food supplies for cormorants in northern Utah as freshwater marshes surrounding the lake were inundated by saltwater. At the same time, annual precipitation in southern Utah was also above normal, which resulted in increases in the amount of cormorant habitat in that area. Consequently, some of the increase in cormorant numbers observed in parts of Utah may have been caused by displacement of birds from the Great Salt Lake marshes. As conditions changed again in the early 1990s, cormorants returned to former habitats in northern Utah. Numbers of birds at locations in southwestern Utah have decreased in general since 1989. Drought conditions in recent years throughout the state have resulted in decreased habitat in southwestern Utah, as evidenced by the loss of nesting areas at Minersville and Piute reservoirs. At the same time, habitat conditions for cormorants in northern Utah have improved to some extent, as the Great Salt Lake receded and freshwater marsh habitat again became more available.

It is possible that collections of cormorants at the three waters where food habits were

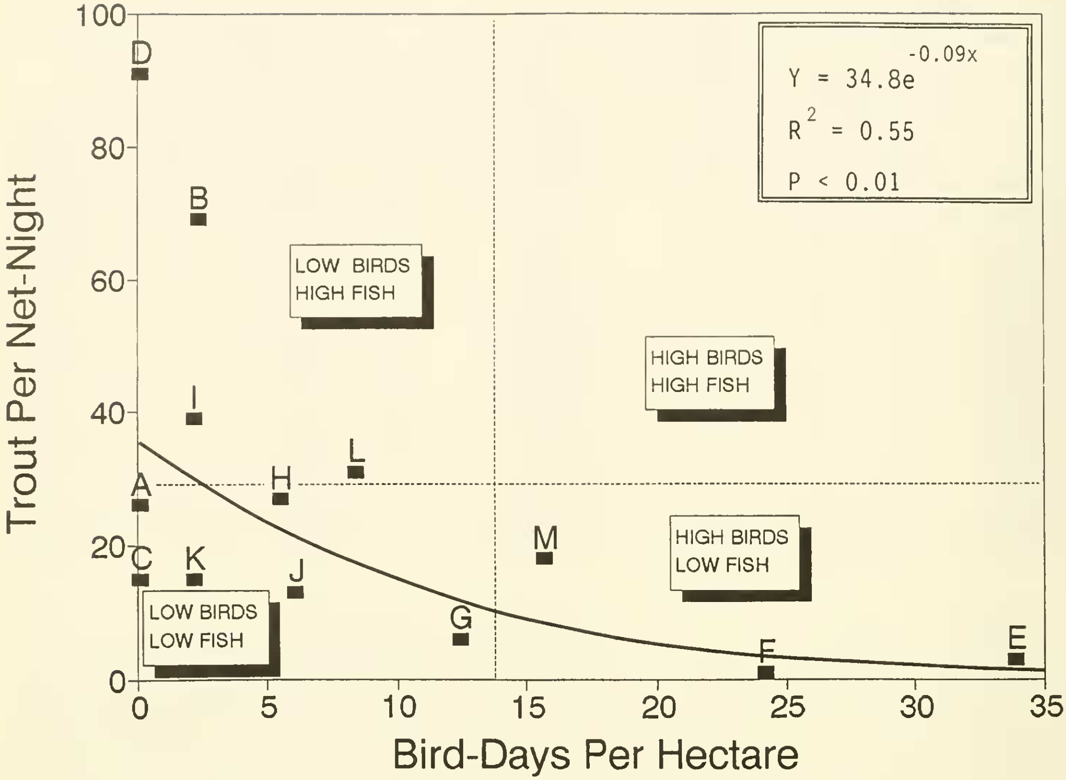

Fig. 1. Regression plot showing relationship between the catch of trout in gill-nets and estimates of cormorant abundance at 13 reservoirs in southwestern Utah, 1989–91. Individual data points are labeled to correspond to location and year as listed in Table 4.

studied could have had some impact on numbers of birds and estimates of abundance following their removal. We collected cormorants only at waters where they were most abundant, however, and felt any impact was minimal. At Minersville Reservoir, for example, the 10 cormorants collected represented a loss of approximately 710 bird-days, or 6.5% of a total of 10,900 bird-days for the year.

Confidence limits for estimates of cormorant abundance (bird-days) averaged 43% of the estimate for reservoirs with high numbers of cormorants (greater than 1000 bird-days). For reservoirs where cormorants were less abundant, confidence intervals were wider, but within reason when absolute values are considered. In many ways the survey of cormorants was more precise than a typical creel survey of fishermen. Count data were less variable and were obtained more directly than in most creel surveys. Numbers of cormorants, for example, were less subject to sudden changes due to weather and did not change because of weekends and holidays. Cormorant fishing abilities and consumption rates were also more consistent and not as variable as catch rates among anglers. Confidence intervals were not included for our estimates of the amount of fish consumed by cormorants. Statistics for cormorant abundance (bird-days) provide some indication of the level of confidence that may be expected for estimates of fish consumption by cormorants (Table 3).

Estimates of annual consumption of fish by cormorants in this study were based on a daily consumption rate of 25% of body weight and an average adult body weight of 1860 g (Ross 1977). However, counts of cormorants at the study waters also included nestlings in some instances. Values calculated for fish consumption where nestlings were present would tend to overestimate actual consumption because of their smaller size and lower caloric intake. Nestlings were present at only one study water, however, and after 25 days of age, their consumption rates are similar to those of adults

TABLE 5. Fish in the diet of Double-crested Cormorants at three reservoirs in southwestern Utah, 1988 and 1989. Data from analysis of stomach contents (SC) from sacrificed adults and regurgitations (R) from nestlings.

			Trout		Utah chub		Smallmouth bass	
Location/date	Sampling method	Sample size / # empty	% of total biomass	Size range (TL, mm)	% of total biomass	Size range (TL, mm)	% of total biomass	Size range (TL, mm)
Minersville Res. 17, 24 April 1988 (from Wasowicz 1991)	SC	16/6	97	65–262	3	—	—	—
Minersville Res. 27 Jul, 29 Aug 1989	SC	10/3	44	100–396	56	76–138	—	—
Otter Creek Res. 4, 24 Aug 1989	SC	10/2	81	322–339	19	48–128	—	—
Piute Res. 4, 24 Aug 1989	SC	10/2	74	145–396	24	62–153	2	110
Piute Res. 29 June 1989	R	6	24	178–300	76	89–275	—	—

(Dunn 1975). Consequently, any overestimate bias was considered to be negligible. Estimates of fish consumption should be considered rough estimates or potential consumption. Nevertheless, it was obvious that cormorants consumed a significant number of fish, including trout, at some reservoirs.

There is a wide range of observation in the literature concerning the impact of cormorants on associated fisheries. Cormorants feed almost exclusively on fish. They are opportunistic feeders and often consume the most available prey item (Trautman 1951, Belonger 1983, Pilon et al. 1983, Craven and Lev 1987). In many instances forage fish have comprised the majority of the diet (Baillie 1947, Craven and Lev 1987, Campo et al. 1988, Carroll 1988), and their impact on sportfisheries was considered negligible. Campo et al. (1988) reported that size and species of fish consumed were highly variable by location and time. They found that cormorants generally consumed forage species unless recreational fish were the predominant species available. In some instances, however, cormorants had a substantial impact on recreational fisheries. Significant predation by cormorants on stocked Atlantic salmon smolts in Maine has been documented for almost 50 years (Cormorant Study Committee 1982). Belonger (1983) estimated that cormorants consumed a total of 1,869,033 yellow perch at lower Green Bay, Lake Michigan, from June through September 1982. In Utah, Wasowicz (1991) estimated that cormorants consumed 9,900 (13%) of 74,000 fingerling rainbow trout during a 2-week period following their stocking at Minersville Reservoir. In addition to the loss of stocked fingerling trout, cormorants ate four times the biomass of larger trout compared to fingerlings. The estimated consumption of catchable-size trout by loons and cormorants at Minersville in 1988 was greater than the estimated sportfish harvest by anglers. Our study suggests that cormorants had a negative impact on some put-grow-and-take trout fisheries throughout southwestern Utah. Potential consumption of trout by cormorants was generally estimated to be higher at the larger, lower-elevation reservoirs. The impact of cormorant predation on sportfish was greatest at Minersville and Otter Creek reservoirs. Potential consumption of trout at those two waters was estimated to be greater than 5 kg per ha for at least one year during the study. Potential consumption of trout by cormorants was moderate (3–4 kg per ha) at Piute Reservoir, Newcastle Reservoir, and Panguitch Lake. The impact of cormorants on sportfisheries at the remaining waters was relatively low.

Although the inverse relationship between cormorant abundance and trout abundance is open to interpretation, it does suggest that predation by piscivorous birds plays an important role in sportfisheries management. A number of factors tend to mask an even stronger relationship between cormorants and trout. For example, survival of stocked trout has been shown to be related to size at stocking, with larger fish generally showing better survival and return to anglers (Burdick and Cooper 1956, Pycha and King 1967, Hansen and Stauffer 1971). Consequently, fishery managers have responded to low survival in southwestern Utah reservoirs by increasing the size and/or number of stocked fish, as well as adjusting stocking times. Reservoirs with histories of low trout survival due to various causes, including bird predation, generally were stocked with larger fish at times when cormorants were not abundant, compared with reservoirs where trout survival was higher. Despite these differential management efforts, an inverse relationship between cormorants and fish abundance has persisted.

Certainly, there are many other biotic as well as abiotic factors that influenced trout abundance in the study waters, as illustrated by instances where both trout abundance and bird abundance were low. At the 13 waters observed during this study, however, there were no instances of a high trout abundance index (greater than 30 fish per net-night) associated with high cormorant abundance (greater than 14 bird-days per ha). Conversely, in all cases where trout abundance was high, cormorant abundance was low. This study was designed to document the abundance of cormorants at waters in southwestern Utah and examine the relationship between cormorant numbers and trout abundance. During the course of the study, it became obvious that many factors, including elevation, reservoir size, and geographic location, influenced numbers of cormorants at a particular water as well as relative abundance of trout. Although determining which environmental factors influenced cormorant numbers at a given water would be of interest, it was beyond the scope of this study.

Cormorants apparently selected trout over other species of fish at the three reservoirs where food habits were studied. All three reservoirs contained relatively dense populations of Utah suckers and/or Utah chubs in addition to trout. Trout, however, may have represented the largest easily available prey item. Knopf and Kennedy (1981) observed that cormorants pursue larger fish in a school.

Certain fisheries are particularly vulnerable to predation by cormorants. The cormorant is able to consume large prey fish (Campo et al. 1988, this study), is able to key on available food sources quickly (Barlow and Bock 1984), and will travel up to 45 km daily to feed (Moerbeek et al. 1987). These characteristics have made aquaculture stations and commercial harvesting operations especially susceptible to predation by cormorants (Schramm et al. 1984, Omand 1947). Many of the recreational trout fisheries in Utah have similarities to aquaculture operations and, consequently, are also vulnerable to predation by cormorants. Utah's sportfisheries typically are managed on a put-grow-and-take basis, where small hatchery-reared rainbow trout are stocked annually. Trout are generally stocked in the spring with the intent that anglers will harvest them after they grow to a catchable size. Stocking often occurs prior to or during the spring migration season for cormorants. Many of the stocked waters also contain few alternate prey species. This scenario often results in a relatively dense population of vulnerable sportfish in waters at the time when cormorant numbers are highest.

Although predation by cormorants and other piscivorous species of birds in Utah represents a serious challenge in sportfisheries management, these birds are also an important component of aquatic ecosystems throughout the West. Their intrinsic value has been recognized by both wildlife managers and the general public, and they have been protected strictly by both state and federal statutes. Dombeck et al. (1984) recognized the importance of incorporating the needs of piscivorous birds into fisheries management objectives. In the past, consideration of avian piscivores has often been restricted to attempts at limiting their potential impact on sportfish or commercial harvest. Methods employed to limit losses of sportfish or commercially valuable fish to bird predation have included gunning, nest and egg destruction, hazing, removal of roost trees, covering aquaculture facilities, and creation of alternative feeding sites. Efforts to control the numbers of cormorants are now regulated strictly under the Migratory Bird Treaty and state statutes. Direct control by gunning is still permitted in some areas under certain circumstances but has been largely ineffective and has generated adverse public opinion where practiced (L. N. Flagg, Maine Department of Marine Resources, personal correspondence). Hazing and construction of physical barriers are impractical at waters other than small ponds. There are a number of measures, however, that can mitigate the impact of cormorant predation on sportfisheries as well as enhance the available habitat for cormorants. In regions where cormorants are primarily migrants, fish stocking should be timed to avoid periods of peak bird abundance. Certain species of sportfish are less vulnerable to bird predation (Matkowski 1989) and might be used in situations where predation is a factor. Given the adaptable nature of cormorants and their mobility, it may also be possible to create alternate habitats where conflicts will not arise. In virtually every region of Utah there are waters with low suitability for sportfish management that might lend themselves to management as "forage" waters for piscivorous birds. Maintaining populations of suitable forage species and providing other elements attractive to cormorants, such as roosting sites and seclusion at selected waters, may at least partially relieve predation pressure on more important sportfisheries. It may be necessary in some instances simply to adjust stocking rates to accommodate some degree of bird predation. At Minersville Reservoir the UDWR has initiated a new sportfish management program integrating piscivorous birds into the overall reservoir management. Proposed changes at Minersville include altering the timing of stocking as well as increasing the size of fish stocked, addition of new species of sportfish, and angling regulations designed to maintain a population of larger trout less vulnerable to predation.

ACKNOWLEDGMENTS

Thanks are extended to many UDWR employees who assisted in data collections. Special thanks go to Joey Comp, Charles Chamberlain, Jack Brawn, Donald Wiley, and Michael Sloane, who conducted most of the counts. Reviews of the manuscript by James Bowns, Southern Utah University, and Donald Archer, UDWR, were greatly appreciated. Funding for the project was provided by the UDWR and Federal Aid in Fish Restoration, Projects F-50-R and F-44-R, Utah.

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Received 1 December 1992
Accepted 18 January 1994